C. DETAILS OF FEDERAL USE ARE INCOMPLETE

Although NTIA makes a reasonable attempt in the Preliminary Report to provide information about federal use of the bands proposed for reallocation,[7] as well as some information on the use of adjacent bands, commenting parties are handicapped by the lack of access to the detailed federal frequency assignment records contained in the Government Master File ("GMF"). Without such access, and on the basis of only the information contained in the Preliminary Report, non-federal users are not fully equipped to assess NTIA's reallocation proposals.

In addition to this inability to identify fully current federal use, the extent of future federal use is difficult to estimate without the results of NTIA's 1992 inquiry on "Current and Future Requirements for the Use of Radio Frequencies in the United States."[8] The report in the Requirements proceeding likely will not be released until September, 1994;[9] long after the public comment and FCC analysis in this Spectrum Reallocation proceeding.

NTIA has indicated that it will provide few, if any, suggestions to the FCC on what specific services should be placed in the various bands to be reallocated, but that it may provide the Commission suggestions on what services should be avoided.[10] The Preliminary Report, for example, indicates a list of Federal systems in the 1710-1755 MHz

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[7] Note, however, that reasons for not proposing the 216-220 MHz band are never discussed in the Preliminary Report.

[8] *Notice of Inquiry* in Docket No. 920532-2132, 57 Fed. Reg. 25010 (June 12, 1992).

[9] NTIA Open Meeting, April 7, 1994 (statement of Mr. Russell Slye).

[10] *Id.* (statement of Mr. William Gamble).

band which must be protected. It would have been helpful, however, if all such information had been provided by NTIA in the Preliminary Report. Without such information, (including specific sharing criteria) commenters are hampered in assessing the true net spectrum and associated potential use.

D. NO PROVISION IS MADE FOR REPLY COMMENTS

NTIA has not provided for reply comments, a staple of federal administrative practice. In general, reply comments are an excellent opportunity for agencies to have the benefit of open deliberation among commenting parties. Unfortunately, by strictly interpreting Title VI's requirements, NTIA chose not provide a period for reply comments. TIA recommends that the FCC provide a period during which it will accept additional "reply" comments on the "initial" comments it will receive from NTIA.

E. THE RISK OF NON-FUNDING FOR REALLOCATION COSTS IS NOT CLEARLY ASSIGNED TO THE FEDERAL AGENCIES

The Preliminary Report notes that the reallocation costs to the federal government and the potential benefits to the public could only be addressed in general terms, because the information required to fully assess federal reallocation costs has not yet been provided.[11] NTIA specifically notes that funds to meet federal users' costs "will need to be provided to the Federal agencies in future appropriations."[12] For presentation in the final report, NTIA

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[11] Preliminary Report *at* p. vi. The information contained in Appendix B, *Id. at* p. B-1, is not particularly informative in this regard.

[12] *Id.*

has asked each affected agency to provide cost estimates for reallocating the candidate bands[13] and, more recently, has provided guidance on how to assess these costs.[14]

NTIA should clarify in its final report that a lack of future funding to federal agencies will not affect availability of reallocated bands to non-federal users. The lack of federal funding to meet the costs of the reallocation decisions made by NTIA should affect only the agencies' ability to continue current operations and/or commence operations at the "new" frequencies. It should not justify the grandfathering of federal users in reallocated spectrum.

III. NTIA'S PROPOSAL TO REALLOCATE THE 2402-2417 MHZ BAND PROVIDES LITTLE IF ANY INCREMENTAL BENEFIT TO NON-FEDERAL USERS

NTIA claims the 2402-2417 MHz band has "potential for new non-Federal radiolocation and fixed and mobile communications technologies, and [is] located in close proximity to the 1850-2200 MHz band recently allocated by the FCC for personal communications services (PCS)."[15] The obvious implication is that this band would be valuable for non-federal fixed and mobile communications, including PCS. TIA believes the analysis that led to this conclusion is seriously flawed and, even though the band is scheduled for "immediate" reallocation, NTIA should reconsider its seriously problematic proposal in the band.

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[13] *Id. at* p. 5-14.

[14] *See* Memorandum re: Guidelines for Estimating Costs of Spectrum Reallocation, from William Gamble, Deputy Associate Administrator, NTIA, to Executive Secretary, IRAC (March 31, 1994).

[15] Preliminary Report *at* pp. v-vi.

A. NTIA's Analysis of the Band Is Flawed

For all practical purposes, the 2402-2417 MHz band already is allocated to exclusive non-federal use. The Preliminary Report indicates that current federal use of this band is limited to military radar testing systems, and that only *five* such systems -- all of them shipborne -- occupy the entire 2360-2450 MHz band.[16] Although it is clear there would be little impact on federal users if the band were reallocated, TIA believes NTIA has overstated greatly the public benefit of reallocating the 2402-2417 MHz band for non-federal use.

1. Noise in the Band Will Have More Impact Than NTIA Estimates

NTIA concludes that "[b]ased on the discussion in Appendix E [of the Preliminary Report], reallocating . . . the 2402-2417 MHz band . . . appears to be a realistic option."[17] TIA believes that the noise from ISM devices,[18] including microwave ovens, and from unlicensed RF devices,[19] makes NTIA's assessment, at best, overly optimistic. At worst, the assessment may be misleading because it suggests that non-federal users economically could utilize the band given the current and growing noise level.

All microwave oven devices are broadband RF generators. The assigned band is 2400-2500 MHz, but the manufacturing industry uses a 20 MHz guard band so that most

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[16] *Id. at* pp. v. and 2-15.

[17] *Id. at* p. 4-17.

[18] *See* Part 18 of the Commission's Rules, 47 C.F.R. § 18.101 *et seq.* (1992).

[19] *See* Part 15 of the Commission's Rules, 47 C.F.R. § 15.1 *et seq.* (1992).

energy is contained within 2420-2480 MHz. There is no signal strength regulation, but EPA has specified a 5 mW/cm^2 leakage limit, and spurious emissions are limited by the Commission's Rules.[20] Although the 2402-2417 MHz band is in a relatively quiet part of the microwave oven band, the charts in Appendix E indicate a substantial noise floor.[21] By virtue of international and domestic regulation,[22] of course, non-ISM operations in the band must accept interference from ISM devices.

NTIA points out that:

> Modern radio technologies, such as advanced error correction, spread spectrum and/or packet-switched methods can very effectively overcome the effects of impulsive noise with little increase in required transmitter power. Using these techniques, up to 10 percent of the transmitted signal can be lost while still providing effective voice communications.[23]

Notwithstanding the fact that NTIA attributes this advice to a memorandum from the Department of Defense which, as noted above, has virtually abandoned the band and uses it only for shipborne radar systems, TIA agrees that robust communications techniques may be available to overcome the noise in the band. These techniques are not costless, however. Indeed, TIA estimates that current and predicted future interference in the band will cause the infrastructure to cost between 2.2 and 50 times the cost of the same system implemented without interference.[24]

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[20] *See* 47 C.F.R. § 18.305 (1992).

[21] *See* Preliminary Report *at* pp. E-3, 4, and 6, Charts E-1 (upper left), E-2 (upper left), and E-5.

[22] *See* Radio Reg. 742, International Telecommunication Union, 1992.

[23] Preliminary Report *at* p. 4-17.

[24] *See* Appendix.

Furthermore, the IEEE 802.11 Committee is developing interoperability standards for high speed wireless links using the 2400-2483.5 MHz band on a Part 15 basis. Reallocating a portion of this band may affect major commercial investments in this emerging world-wide market for wireless computer links.

2. Sharing with the Amateur Service Would Be Difficult

In determining whether bands meet Title VI's band selection criteria, NTIA was to consider "the extent to which, in general, commercial users could share the frequency with amateur radio licensees."[25] TIA is unaware of any previous experience of commercial sharing with the radio amateur service except under Part 15 of the FCC's Rules.[26] The 2402-2417 MHz band, which is allocated on a secondary basis to the amateur service, comprises part of the spectrum known in the amateur community as the 13 cm band. NTIA believes the band is "very lightly used by radio amateurs, as compared to lower frequency bands,"[27] and that "the amateur community can satisfy the majority of their [sic] spectrum requirements in the 13 cm band in the remaining 35 MHz [of the 13 cm band]."[28] Unfortunately, no definitive analysis is revealed to substantiate and quantify this claim.

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[25] Title VI, *to be codified at* § 113(c)(3).

[26] *See* 47 C.F.R. § 15.1 *et seq.* (1992).

[27] Preliminary Report *at* p. 5-12.

[28] *Id.*

To the contrary, the Preliminary Report indicates that the Amateur Radio Relay League ("ARRL") predicts increased amateur use of the 2390-2450 MHz band,[29] and that the 2402-2417 MHz band is part of the authorized bands of the Radio Amateur Civil Emergency Service.[30] Indeed, it appears from one set of comments already received by NTIA, that the loss of 13 cm amateur radio spectrum could "have a negative effect on public safety, particularly in the larger urban areas of our nation."[31] Whether or not this or the ARRL's claim are true, it is apparent that amateur radio interests will oppose any reallocation of the band to new non-federal services, and that this opposition may be able to cite effectively the increasing amateur use of the band for public safety activities. Even if their opposition is not successful, surely it will be difficult to arrange sharing with amateur licensees in this band.

B. The Proposed Reallocation Does Not Meet the Letter or Spirit of Title VI

The fact that the band's usefulness is seriously curtailed by ISM and amateur operations already present, it does not meet Title VI's requirement that the bands considered "are most likely to have the greatest potential for productive uses and public benefits . . . if allocated for non-federal use."[32] Indeed, as NTIA noted, "simply identifying the bands that

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[29] *Id. at* p. 4-16.

[30] *Id. at* p. 3-6.

[31] Letter re: Communications Licensing and Spectrum Allocation Improvement, to Norbert Schroeder, Program Manager, NTIA, from Jerry Boyd, Chief of Police, City of Martinez, CA (March 21, 1994).

[32] Title VI, *to be codified at* § 113(a)(5).

have the absolute minimum impact on the Federal agencies would not meet the intent of Title VI with regard to the public benefit."[33] TIA believes the proposed reallocation of the 2402-2417 MHz band does not meet the requirements of Title VI. NTIA immediately should reconsider this proposal.

Because the incremental public benefit of reallocating the 2402-2417 MHz band is highly questionable, TIA certainly believes the proposed reallocation does not meet the spirit of Title VI. Furthermore, even though TIA recognizes the inherent tension between the ease of federal systems withdrawal and the added public benefit of reallocating a shared band, for all practical purposes the band already is allocated exclusively to non-federal use. This fact simply means that the proposed allocation does not meet the spirit of Title VI, which requires that all bands considered for reallocation be allocated to federal use on a primary basis.

C. The FCC Has Initiated an Inquiry on This Band and Immediate Reconsideration by NTIA Is Warranted

On April 20, 1994, the FCC adopted a notice of inquiry into possible uses for the 2390-2400 MHz, 2402-2427 MHz, and 4660-4685 MHz bands after they are reallocated for non-federal use.[34] The Commission is moving quickly in response to the requirements of Title VI and has identified its goals for the bands:

> The Commission's goal is to ensure that spectrum reallocated for private sector use will provide for the introduction of new services, and the enhancement of existing services. These new and enhanced services will create new jobs, foster economic growth, and improve access to communications by industry and the American public.

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[33] Preliminary Report *at* p. 5-14.

[34] Allocation of Spectrum Below 5 GHz Transferred from Federal Government Use, ET Docket 94-32, FCC 94-97 (released April 20, 1994).

> Possible advances in communications will contribute to the development of the national information infrastructure which will provide American industry and consumers access to rapid and flexible information networks essential to competition and the global market.[35]

Clearly, the FCC has some noble and ambitious designs for the 50 MHz reallocated from federal use. For all of the reasons stated in this section, TIA believes that it will be extremely difficult to achieve the Commission's goals in a band with as many problems as 2402-2417 MHz presents. Further, it is clear that the band would produce little or no incremental benefit to NII development efforts. Based on initial studies, TIA estimates that not more than 2 MHz of the 15 MHz offered in the 2402-2417 MHz band is usable as an incremental increase in spectrum for the private sector. Accordingly, TIA believes that the net spectrum specified for the 50 MHz initial transfer required by Title VI is inadequate, and that NTIA quickly should move to reconsider its preliminary proposal for this band.

IV. NTIA'S REALLOCATION PROPOSALS RAISE TECHNICAL CONCERNS WHICH SHOULD BE TAKEN INTO ACCOUNT BY NTIA AND THE FCC

As could be expected, all of the bands proposed for reallocation raise issues affecting the viability for non-federal use. Nonetheless, TIA is confident that manufacturers will rise to the challenge and develop product that utilize this spectrum.

In general, TIA is concerned that the technical characteristics of these bands do not lend themselves particularly well to paired frequency use for traditional half-duplex land mobile operations. The proposed bands for reallocation below 3 GHz are generally small

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[35] *Id.*

sized blocks of 5-10 MHz with little probability of aggregation.[36] While applications can surely be developed to utilize the proposed spectrum, the deficiency to address the continued need for wide area land mobile systems must be addressed in the very near future through NTIA or FCC actions.[37] TIA's specific concerns for the bands other than 2402-2417 MHz, which are discussed in detail above, are described in the following subsections.

A. THE 1390-1400 MHZ BAND

This band currently is used by long-range air defense radars, military test range telemetry links, tactical radio relays, and radio astronomy. According to NTIA, the band has potential for new non-federal fixed, mobile, and radiolocation communications technologies and applications.[38] However, high-powered FAA and DoD radars will continue to operate in the lower adjacent band and radio astronomy observations apparently will continue within the band. Thus, reallocating this band for non-federal use would require that airborne transmissions be prohibited to protect radio astronomy, and that the FAA and DoD install filters on their adjacent band high powered radars. TIA notes that new

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[36] TIA believes that mobile operations lend themselves particularly well to frequencies below 3 GHz. TIA believes that NTIA and the FCC should continue to rely upon this general rule in its allocation decisions for the foreseeable future and, therefore, recommends that frequencies below 3 GHz be considered primarily for mobile operations. Fixed operations have greater flexibility to operate in bands above 3 GHz.

[37] In this regard, TIA notes that the FCC received a Petition for Rule Making filed by the Coalition of Private Users of Emerging Multimedia Technologies -- filed on December 23, 1993 -- to allocate spectrum to accommodate advanced private land mobile services. TIA supports the initiation of a proceeding to explore issues raised by this petition and further believes that such an allocation, coupled with FCC action at 2 GHz for public PCS systems, is necessary to address the near-term future land mobile needs of this country.

[38] Preliminary Report *at* p. v.

equipment designed for use in this band must be capable, at some expense, of tolerating adjacent band FAA and DoD high power radar signals.

Further, it is not clear why NTIA did not include the entire 1350-1400 MHz in its Preliminary Report. NTIA's own study of usage in various bands released in May, 1993, concludes the current use of the 1350-1400 MHz band is low with only a 1% expected growth rate for assignments in the band.

B. THE 1427-1432 MHZ BAND

This band is used for military tactical radio relay communications and military test range aeronautical telemetry and telecommand. NTIA believes the band has potential for new non-federal fixed and mobile communications technologies and applications.[39] In order to protect sensitive radio astronomy observations in the adjacent band, reallocation for airborne or space-to-Earth communications would have to be avoided. TIA notes that protection of adjacent band radio astronomy operations could make this band difficult to use.

C. THE 1670-1675 MHZ BAND

Internationally, this band is used by a broad range of services including fixed, mobile, and meteorological services. NTIA believes the band has potential for new non-federal fixed or mobile communications and that reallocation for airborne or space-to-Earth communications should be avoided in order to protect sensitive radio astronomy observations

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[39] *Id.*

in the adjacent band.[40] TIA believes that before non-federal users can use this band, the federal meteorological services will have to be redesigned or replaced. Also, TIA cautions NTIA that the adjacent band radio astronomy operations may make this band difficult to use.

D. THE 1710-1755 MHZ BAND

This band is used extensively for fixed microwave communications, military tactical radio relay, and airborne telemetry systems. NTIA claims the band has potential for new non-federal fixed and mobile services.[41] Title VI, however, requires that microwave communication systems operated by federal power agencies in this band receive certain protections, which will restrict non-federal use. These federal systems and safety-of-life systems, which also receive protection under Title VI, will be allowed to continue. In addition, essential military operations at 17 sites will continue. TIA cautions NTIA that the various usage restrictions may make this band difficult for non-federal use. Because this band represents 90% of the mixed use reallocation below 3 GHz, it should be made available in three to five years, rather than the proposed 10 years, in order to help alleviate immediate land mobile spectrum needs. Further, NTIA should consider "repacking" those remaining federal users into 10 or 20 MHz, especially in spectrum-deficient urban areas. Continuing federal operations on all 45 MHz will seriously inhibit non-federal land mobile operations.

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[40] *Id.*

[41] *Id.*

This concern may be irrelevant, however, as NTIA proposes that reallocation of the band to non-federal use take place nearly ten years from now.

E. THE 2300-2310 MHZ AND 2390-2400 MHZ BANDS

These bands are used by the military for radar testing systems, such as target scattering and enemy radar simulators, and for telemetry systems. The amateur service also is allocated in these bands on a secondary basis. NTIA states that the bands have potential for new non-federal radiolocation and fixed and mobile communications technologies, and points out that they are located in close proximity to the 1850-2200 MHz band recently allocated by the FCC for PCS.[42] TIA cautions NTIA that the highly sensitive receivers and/or high power transmitters of NASA's deep space network in the adjacent bands may make these bands difficult to use. Further, TIA is concerned that commercial sharing with the amateur service may be difficult.

F. THE 3650-3700 MHZ BAND

This band is used by Navy air traffic control radars on board aircraft carriers and is allocated to a number of different radio services around the world. NTIA believes the band could be used for new non-federal technologies in the fixed, mobile (except aeronautical),

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[42] *Id. at* pp. v - vi.

fixed-satellite, and radiolocation services.[43] Adopting regulatory or industry receiver standards for the new equipment would enhance band sharing.

G. THE 4635-4660 MHZ BAND

This band is used for military airborne telemetry and high-powered tropospheric scatter communications systems. NTIA believes the band has potential for a variety of new non-federal fixed, mobile, and fixed-satellite technologies and associated applications.[44] Essential Federal airborne operations, however, will be continued for 15 years at three sites and there will be a three-year delay to re-design certain military telemetry systems.

H. THE 4660-4685 MHZ BAND

This band is used for military airborne telemetry and high-powered tropospheric scatter communications systems. According to NTIA, it has potential for a variety of new non-Federal fixed, mobile, and fixed-satellite technologies and associated applications.

V. NTIA SHOULD FORM A PARTNERSHIP WITH THE PRIVATE SECTOR TO DEVELOP PROCEDURES THAT MAXIMIZE FEDERAL ACCESS TO FREQUENCIES WHILE SATISFYING FEDERAL SPECTRUM NEEDS

TIA recognizes the demands placed upon NTIA through the Congressional legislation particularly with respect to timing. Although TIA supports expedited action -- and expedited reallocations -- it believes that the process employed has not yielded the most efficient means

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[43] *Id. at* p. vi.

[44] *Id.*

of identifying target spectrum bands consistent with the intent of Congress. TIA therefore recommends that the communications industry and the federal government develop a better partnership for future analytical review of U.S. spectrum allocations. Even if industry is unable to influence the instant proceeding, such a partnership will prove immensely beneficial in improving each side's understanding of the other's spectrum needs. Because there certainly will be future reallocation decisions dictated by both domestic and international requirements, a better relationship will allow the process to operate in a more efficient manner.

TIA therefore strongly recommends that NTIA seek broader public participation in ascertaining the spectrum needs of the private sector. Such participation should go beyond the formal spectrum inquiries previously employed by NTIA. Rather, private industry and federal government spectrum users should be provided an open forum to raise issues of concern to both. Through increased understanding, NTIA and the private sector can make more reasoned decisions on sharing spectrum in a way satisfactory to both sectors.

VI. CONCLUSION

NTIA should be congratulated for the substantial Preliminary Report it produced under demanding time constraints. The agency has shown little procedural flexibility, however, in dealing with non-federal entities. This rigid adherence to the requirements of Title VI seriously diminishes the value of public participation in the reallocation decisions. Further, NTIA has missed the spirit and perhaps the letter of Title VI in several substantive areas. For example, significant non-federal use already is in place in many of the proposed

bands, making questionable the incremental value of their reallocation; high power federal transmitters and highly sensitive receivers (for radio astronomy and the deep space network) will continue in spectrum adjacent to some proposed bands; and it is difficult for private sector services to share with the amateur service. TIA has suggested that there may be ways yet to correct the procedural and substantive problems with the Preliminary Report before NTIA issues a final report. These problems will be corrected only if both NTIA and the FCC are flexible and work together and with industry to solve them. TIA welcomes the opportunity to participate further in this matter before both agencies.

Respectfully submitted,

TELECOMMUNICATIONS INDUSTRY ASSOCIATION

George M. Kizer
Chairman, Fixed Point to Point
Communications Section

Jesse Russell
Chairman, Mobile and Personal
Communications Division

Eric Schimmel
Vice President

2001 Pennsylvania Ave., NW
Suite 800 Washington, DC 20006
(202) 457-4990

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APPENDIX

I. SUMMARY

In this Appendix, robust modulation applied to potential use of the lower portion of the 2.4 GHz ISM band is analyzed. The cost penalty for infrastructure varies from 2.2 times to 50 times as much as the cost of the same system implemented in a band without the interference that is -- or is hypothesized will be -- in the band in the future.

II. INTRODUCTION

In the Preliminary Report, NTIA proposes that the 2402-2417 MHz band be shared with microwave ovens by using a robust form of modulation such as spread spectrum. The agency supports this proposal with the fact that a mobile satellite service was recently allocated for sharing in the upper portion of the ISM band where the emissions from microwave ovens are lower than elsewhere in the ISM band, and that this service proposes to use spread spectrum on the space-to-earth link at these frequencies. It is instructive to note that the major proponent of the service has abandoned its plans as of this writing.

Further, there are existing private operational fixed stations, TV pickup mobile stations, and inter-city relays which use the band with analog radios. However, NTIA points out that the "receivers are generally located in non-urban areas. Many of the low-capacity fixed links are for off-shore communications."

Yet the NTIA suggestion to use spread spectrum modulation remains. So it is instructive to analyze the impact on a service that might use the ISM band in the presence of signals produced by devices including microwave cooking ovens, light controllers, heaters, etc. It is the purpose of this Appendix to determine the impact on an example service, DMBA cellular communications, if it were located in the proposed lower portion of the 2.4-2.5 GHz band.

III. INTERFERENCE PLANNING FACTOR

Appendix E of the Preliminary Report indicates that the noise in the middle portion of the band "approaches a thermal noise characteristic" as measured in major metropolitan areas. It also is said that the band edges have significantly lower noise power and that it is impulsive in nature. It is these characteristics that may make use of that portion of the band possible.

However, one should recognize what has happened to the temporal characteristics of this band over time. At first, there were few devices that occupied the band, and the noise floor remained near kTB in any receiver. When interference was produced in any portion of the band, it was impulsive in nature. Over time the use of the band grew and, as the number of signals grew, the nature of the band changed to its current state.

It is very reasonable to hypothesize that the band will continue to mature. As that takes place, those portions of the band that show impulsive noise will approach a more thermal noise nature. Measurements have been reported that characterize the band in the 1991 time frame.[1] The measured received signal level is presented for five major American cities. The minimum, maximum, and mean is presented as taken over a period of 30 minutes at each of several sites, so the amount of time spent at any frequency is relatively small.

The minimum in the band from 2402-2417 MHz is flat and virtually identical for all of the 5 cities, -134 dBm out of a 0 dBi antenna. The resolution bandwidth for these measurements is reported to be 10 kHz, and kTB at 290 degrees. Because k is -133.98 dBm, it is concluded that these minimum levels are a measurement of the ambient noise floor. The mean is also flat and very close to the same in the 5 cities, -127 dBm; this is a 7 dB rise from the noise floor. It is suggested by this author that the noise at this level may also be very Gaussian; if it is not now, it will be soon as the band continues to mature.

In New York, San Francisco, and Los Angeles the maximum for all except the highest few peaks is -100 dBm a noise rise of 34 dB. For Chicago and Dallas that level is -118 dBm, a rise of 16 dB. Going forward, we will look at these various such levels to become the Gaussian noise floor in this band.

IV. EXAMPLE ANALYSIS

It goes without discussion that the sharing of the band is possible outside of the major metropolitan areas. There, the use by ISM Part 15 services is so small that the noise produced is negligible. However, there is no spectrum crowding in those geographical areas, so it is a mute point. It is also possible to share frequencies in the 2.45 GHz ISM band in major metropolitan areas, and it is here that it can potentially provide significant spectral relief. At issue is the effectiveness of any proposed new sharing utilization.

The success of the Cellular service has exceeded virtually all expectations, and the need for additional spectrum at some point is unquestioned. Therefore, it is appropriate to consider use of Cellular CDMA in the proposed sharing of the ISM band.

The use of CDMA in the Cellular service is not a new idea; QUALCOMM has demonstrated a breadboard system in San Diego, CA in 1989, and conducted an extensive field trial in 1990 in Manhattan with NYNEX Mobile.[2] The capacity of such a system is given by

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[1] Spectrum Usage Measurements in Potential PCS Frequency Bands, NTIA Report 91-279 (Sept. 1991).

[2] Allen Salmasi and Klein S. Gilhousen, On the System Design Aspects of Code Division Multiple Access (CDMA) Applied to Digital Cellular and Personal Communications Networks, 41st IEEE Vehicular Technology Conference Record, May 19-22, 1991, pp 57-62.

$$N = \frac{W}{R} \bullet \frac{1}{E_b/N_o} \bullet \frac{1}{D} \bullet F \bullet G$$

where:
N = Calls per cell
W = Spread Spectrum Bandwidth
R = Data Rate
E_b/N_o = Required Bit Energy / Noise Power Spectral Density
D = Voice Duty Cycle
F = Frequency Reuse Efficiency
G = Number of Sectors per Cell.

All CDMA systems have a capacity equation that is similar, and the capacity is limited by the signal to interference ratio that results from all sources that are within range of the victim receiver. If any one subscriber unit is close to the base site in the cell, and transmitting full power, it can significantly reduce the capacity of the cell. In the design of such a system, therefore, considerable effort is given to minimizing the amount of signal transmitted by any one user. Power control is adjusted rapidly in about 1 dB steps to maintain a constant received power at the base.

The ratio E_b/N_o used in the QUALCOMM design required a minimum of 6 dB, and permitted up to 120 channels of capacity. Others use a more conservative value such as 8 dB, but for all designs there is a minimum required value. Subscriber units must have a power output that will permit this E_b/N_o at the maximum range required by the Cellular base station layout.

The increase in ambient noise floor impacts the design of the Cellular system. There are two ways to address that limitation for the integration of a CDMA system into the ISM band. First, the range of the subscriber unit may be reduced requiring the addition of more base sites in the cellular design to maintain coverage over the whole geographic area. Second, the power transmitted by the subscriber unit may be increased to maintain the E_b/N_o at the same level it was without the interference present.

The second is practically impossible to do. A subscriber unit with 1/2 Watt which would work in a band with no other interferers than the co-channel CDMA users, with suitable margin, would require 7 dB more power, or 2.5 Watts to function in an environment with the measured average power level in the five cities.[3] If, however, the Gaussian noise level were 16 or 34 dB above kTB in the future as suggested above, that same portable would need to transmit 20 or 1,250 Watts respectively. It is self evident that the latter two are not realistic. The 2.5 Watt unit might be briefly considered by some, but the current drain from any realizable size battery is prohibitive.

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[3] *See* NTIA Report 91-279, footnote 1, *supra*.

The first case, where additional base sites are added, is prohibitive from a cost perspective. The infrastructure necessary to support the subscriber units must be in place with coverage over the whole metropolitan geographic area before mobiles and portables can be placed on the system. More required sites means more cost per user.

This can be quantified for the three levels of degradation identified above, 7 dB, 16 dB, and 34 dB. If each cell site is designed to have a 15 km range (707 sq. km area) in an environment without the interference, and a 4th low propagation model is assumed (typical for an urban environment), then to a first order, the ratio of the areas covered when the interference is not present to the area when the interference is present is the factor of the number of additional cells required. The number of cells required is 2.2, 6.3, and 50 times more respectively for the interference identified above than when no interference is present. This translates directly into cost, and makes the use of the lower portion of the ISM band prohibitively costly to use for this service.

V. CONCLUSION

The interference that will be in the 2402-2417 MHz band results in expensive systems solutions to mitigate against the interference that will result even when a robust form of modulation such as spread spectrum is used. Packet radio also requires additional capacity in the form of power output to overcome the interference or additional base sites to allow for the re-transmission of the packet when interference takes place, though no attempt is made to quantify that here. TDMA with FDMA could also use these techniques to overcome the interference, but the penalty for overcoming the interference is even more severe.